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Approaching location-based services from a place-based perspective: from data to services?

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ABSTRACT

Despite the seemingly obvious importance of a link between notions of place and the provision of context in location-based services (LBS), truly place-based LBS remain rare. Place is attractive as a concept for designing services as it focuses on ways in which people, rather than machines, represent and talk about places. We review papers which have extracted place-relevant information from a variety of sources, examining their rationales, the data sources used, the characteristics of the data under study and the ways in which place is represented. Although the data sources used are subject to a wide range of biases, we find that existing methods and data sources are capable of extracting a wide range of place-related information. We suggest categories of LBS which could profit from such information, for example, by using place-related natural language (e.g. vernacular placenames) in tracking and routing services and moving the focus from geometry to place semantics in location-based retrieval. A key future challenge will be to integrate data derived from multiple sources if we are to advance from individual case studies focusing on a single aspect of place to services which can deal with multiple aspects of place.

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1. Introduction

Location-based services (LBS) are, we suggest, all about place. Delivering relevant information presupposes that we understand the context of an information need, be that in the form of a need to navigate from one location to another (Kurashima et al. 2010), a desire for information about available services around a users' current and forecasted location (Poslad 2001) or interactions with a dialogue based virtual assistant (Bartie et al. 2018). Treating such context as simply spatial information, for example, as a set of coordinates, flies in the face of what we understand about how people interact with places.

Thus, for example, places have names (Coates 2006), which form an efficient shorthand for communicating about location without a need to resort to complex coordinate systems, and yet allow us to zoom in and out with

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minimal cognitive effort (e.g. Richter et al. 2013). They have properties, in the sense of their physical materiality (Relph 1976), which in turn can reflect affordances and activities (Lansley and Longley 2016) associated with particular places at particular times (Mckenzie and Adams 2017). They are related, in that they may be contained by, overlap with or be distinct from other places (Schlieder, Vögele, and Werner 2001). Furthermore, individuals and groups may associate particular places with experiences and emotions, giving rise to the notion of sense of place (Shelton, Poorthuis, and Zook 2015). Place, in short, represents a shared meaning, and in turn, should be viewed as an indispensable form of context for LBS (c.f. Farrelly 2014).

This importance of place as a component of context is emphasised in Dey's seminal paper, where he defines context as:

> …any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves (Dey 2001).

Implicitly, according to this definition places can both *be* context in the form of information characterising an entity, but also take the role of an entity, and thus *have* context. Despite this obvious importance, attempts to deal with place in LBS, and more broadly geographic information science, are piecemeal and disconnected. They essentially fall into three camps. The first uses place as a shorthand for location and make no distinction between places and other sorts of locations. Perhaps the most obvious example is the definition of place in schema.org as 'Entities that have a somewhat fixed, physical extension[1]'. This definition reduces places to geometric objects, and while not *per se* wrong, it effectively ignores the nuances presented above and treats places as objects represented in some entity-based model of space. For example, Villegas et al. (2018) introduce the idea of location context, where a place is treated simply as a location:

> Location context: Refers to the place associated with an entity's activity (e.g. the city where a user lives). This category is sub-classified as physical (e.g. the coordinates of the user's location, a movie theater's address, or the directions to reach the movie theater from the costumer's current location), and virtual (e.g. the IP address of a computer that is located within a network) (Villegas et al. 2018).

While we do not dispute the utility of this definition, we argue that it ignores the potential richness of place as a source of context. Even where the notion of location as a social and dynamic construct is recognised (e.g. Gasparetti 2017) theories relating to place as a concept appear to be neglected despite their potential utility in better understanding and modelling context.

A second strand of work considering place concentrates on deriving general models of place, most often starting from the literature in human geography, and aiming to describe a conceptual data model suitable for

dealing with place in information systems (e.g. Jordan et al. 1998; Jorgensen and Stedman 2001; Winter and Freksa 2012). These attempts are useful and interesting, but unfortunately, they have typically stopped at the conceptual level, and thus have had limited influence on the third set of approaches.

This third group is fuelled by the opportunities offered by social media and user-generated content as data sources allowing access to a seeming 'avalanche of data'. Here, place is used as a motivation and exemplar attributes are operationalised (e.g. Hauthal and Burghardt 2013; Richter et al. 2012), though typically not further utilised in providing specific services.

Our aim in this paper is to bring together the second and third strands of research identified above and contribute to the first, focussing on place as a form of contextual information in LBS, which we suggest could benefit from considering the concept of place in more detail. We, therefore, analyse existing data-driven research to explore how authors have extracted place-related context. Based on this analysis, we identify ways in which the use of place as context could enhance specific tasks in LBS related to navigation and tracking, marketing and location-based information retrieval.

2. Exploring place in data-driven research

Since our aim was to use existing works exploring aspects of place, we performed a literature review. A major challenge in finding papers related to place is that, as we have demonstrated above, place is often simply used as a synonym for a geometric location on the one hand, and on the other not all papers dealing with place do so explicitly. Therefore, searching for literature using keywords alone is not helpful and might be misleading. To select a broad range of relative literature we used a combination of purposive and snowball sampling (Wohlin 2014).

As a starting point, we selected three papers known to us (Chesnokova, Nowak, and Purves 2017; Jenkins et al. 2016; Shelton, Poorthuis, and Zook 2015), from different research groups, including a variety of aspects of place which we wished to cover in our study. Moreover, we identified four criteria to identify further papers for our list in the next step of 'snowballing'.

- Papers must be data driven and have extracted place properties from some form of web accessible content such as Wikipedia, Twitter, Foursquare, etc. (this criterion excludes purely conceptual papers).
- Papers must capture some form of shared meaning of place. Therefore, place properties have to be generated by identifiable multiple contributors. This criterion enables us to know more about who creates descriptions, that is to say, the social aspect of place.

- Papers aim to derive properties for places, rather than attributing existing point of interest data.
- Finally, we were only interested in papers where place properties varied in space, since otherwise, such information is not useful contextual information for LBS.

Only articles which met all of these criteria were retained, and we did not aim to find an exhaustive, but rather a representative set of papers. Representativity in our study implied diversity in the set of four aspects described below, which we used to analyse our papers. It is thus important to make clear that the process of paper selection was iterative, and necessarily subjective. Thus, for example, the seed set of papers we chose included a paper from our research group, and the papers cited by these works unsurprisingly reflect a particular research network (Skupin 2014).

After carrying out our snowballing process, all selected articles were characterised according to the following four aspects: research rationale, sources of place data, data characteristics, and place dimensions.

To understand the **rationale** behind each article, we looked at the *application domain* (if applicable) targeted by the study and the *motivation* given for exploring place descriptions. In exploring **data sources**, we not only listed data sources, but also analysed the ways in which data were retrieved. The third aspect we studied concerned the **characteristics** of the data collected. For example, the *study area* and the *time span* associated with the dataset, what techniques, if any were used to *localise* data with respect to places and, finally, in what *language* data were created. The final aspect we explored related to the **place dimensions** accounted for in a paper. We compared these with a model from information science (Shatford 1986), and classified papers according to the *where* facet of the Panofsky–Shatford facet matrix. Thus, we categorised papers as addressing one or more of the following dimensions: the *specific of* (related to named places or instances of places), *generic of* (properties or features of places), and the *about* (associated emotions and feelings).

3. Findings

In total, we selected 18 articles for further examination (Table 1). All of the articles were published between 2010 and 2018, reflecting both our initial set of seed articles, and the recent and increasing popularity of such data-driven research.

3.1. Rationale

Of the 18 papers we identified, only two (Huang 2016; Ye et al. 2011) made direct proposals for applications in LBS. The next group of papers made general claims about applications in landscape studies, for example, with

Table 1. The list of selected papers about place and their year of publication.

Year of publication	Selected articles
2010	(Hollenstein and Purves 2010)
2011	(Ye et al. 2011)
2013	(Adams and McKenzie 2013; Hauthal and Burghardt 2013)
2015	(Dunkel 2015; Hobel, Fogliaroni, and Frank 2016; Shelton, Poorthuis, and Zook 2015)
2016	(Capineri 2016; Derungs and Purves 2016; Gliozzo, Pettorelli, and Haklay 2016; Huang 2016; Jenkins et al. 2016; Resch et al. 2016)
2017	(Chesnokova, Nowak, and Purves 2017; Gao et al. 2017; Mckenzie and Adams 2017)
2018	(Chen, Parkins, and Sherren 2018; Lim et al. 2018)

respect to aesthetics, cultural ecosystem services and more generally the perceived environment (Dunkel 2015; Gliozzo, Pettorelli, and Haklay 2016; Derungs and Purves 2016; Chen, Parkins, and Sherren 2018; Chesnokova, Nowak, and Purves 2017). Interestingly, these papers focused mostly on non-urban environments, while a further group was motivated by exploring properties of cities, with reference to both inequality and the need for more nuanced ways of analysing such data (Shelton, Poorthuis, and Zook 2015; Capineri 2016). All of these papers made claims about application domains focussing on understanding specific places and their properties. A related group of papers also focussed on urban areas, but zoomed into the emotions experienced and reported in such places by individuals (Hauthal and Burghardt 2013; Resch et al. 2016; Lim et al. 2018). In contrast to the earlier works, Lim et al. (2018) quantitavely compare the difference between sentiment associated with green and other urban spaces. The potential of user-generated content as a way of finding out more about how places are named, in the sense of the (vague) footprints associated with vernacular usage of placenames is explored by three papers (Hollenstein and Purves 2010; Hobel, Fogliaroni, and Frank 2016; Gao et al. 2017). A final group of three papers essentially focussed on exploring and deriving thematic regions, associated with or forming places, and have a clear methodological rather than application focus (Adams and McKenzie 2013; Jenkins et al. 2016; Mckenzie and Adams 2017).

A number of points are worth making here. Firstly, and contrary to our initial expectations, we found that papers dealing with place focus on both urban and rural landscapes, and thus that contextual information in both settings appears to be available. Secondly, many of the papers made strong arguments as to the availability of new data sources and their potential for allowing contextual information related to subjective experiences of places, be that in the context of their naming, properties or emotions related to them. Thus, a key motivation for such research is clearly pragmatic and data driven. Thirdly, and importantly, direct applications in LBS reflecting more complex conceptualisations of place, or indeed even arguing for its importance, were rare in our sample despite, we would argue, their obvious importance.

3.2. Data sources

Data-driven research requires data – and the choice of data may have implications for the conclusions which can be drawn. In terms of place for LBS, it is important to understand, for example, not only which places are represented, but also by whom and when. Just as important as what we can derive from such data are the gaps – the things which are not said, but which might be equally important in capturing aspects of place. For example, which communities produced the data (and thus who did not participate), which places are mapped (and thus which are ignored), and what objects or emotions are more commonly shared.

We identified four broad categories of data which were used in the papers we explored. The first, images and their associated metadata, have been argued to potentially provide an immediate and direct link to place (Fisher and Unwin 2005). We identified three sources of such data in the papers we analysed: Flickr, which was most common (Capineri 2016; Dunkel 2015; Gao et al. 2017; Gliozzo, Pettorelli, and Haklay 2016; Hauthal and Burghardt 2013; Hollenstein and Purves 2010; Huang 2016), Instagram (Chen, Parkins, and Sherren 2018; Gao et al. 2017; Mckenzie and Adams 2017) and the now defunct Panoramio (Gliozzo, Pettorelli, and Haklay 2016; Hauthal and Burghardt 2013). We note that the popularity of Flickr might be attributable to the relatively straightforward access to data, with all non-private images and their metadata being accessible through the Flickr API, and both spatial (e.g. using a bounding box) and textual (e.g. using a term like *Downtown)* queries being straightforward to implement. By contrast Instagram's API is no longer easily accessible and the terms of use of the data are more complex. However, it has been argued that the Instragram community is broader than that of Flickr, potentially providing access to a wider range of place descriptions (Di Minin, Tenkanen, and Toivonen 2015; Gao et al. 2017). All three sources focus on the use of tags as a way of both indexing content (Mountain and MacFarlane 2007) and improving searchability (and thus visibility). Importantly, images taken, uploaded and tagged on Flickr and other image sharing platforms are not randomly sampled – they represent popular places (Crandall et al. 2009), are often part of a narrative (Davies 2007) and have been argued to be indicators of aesthetics and recreation in a landscape context (Van Zanten et al. 2016). One source of ambiguity concerns the locations associated with image metadata. Typically, these are the location of the photographer, though users may also associate images directly with the location of content. A fourth source of image data was the Geograph platform, used by Chesnokova, Nowak, and Purves (2017) and Gliozzo, Pettorelli, and Haklay (2016). Here, images are related to 1-km grid squares and associated with textual descriptions, which can then be analysed.

The second broad group of data used are microblogs, exclusively in the form of Twitter data (Capineri 2016; Gao et al. 2017; Jenkins et al. 2016; Mckenzie and Adams 2017; Resch et al. 2016; Shelton, Poorthuis, and Zook 2015; Lim et al. 2018). Twitter's popularity, like that of Flickr, is mostly ascribable to its ease of access through an API, though in contrast to Flickr data, historical data are difficult to obtain. Indeed, most researchers only have access to some small proportion of the total volume of Tweets. Twitter messages are short, often with a relatively simple language structure (Dittrich, Richter, and Lucas 2015), covering a wide variety of topics without a focus on specific domain (Go, Bhayani, and Huang 2009; Kwak et al. 2010) and are a popular source for research, despite a wide range of challenges including a high frequency of misspelling and slang (Go, Bhayani, and Huang 2009), the use and mixing of multiple languages (Hong, Convertino, and Chi 2011), the prevalence (especially, it appears, in geocoded Tweets) of bots (Chu et al. 2010; Compton, Jurgens, and Allen 2014) and the fundamental question of whether or not location is strongly correlated with the topic of discussion in a Tweet (Hahmann, Purves, and Burghardt 2014). In terms of LBS this is of crucial importance, since, unlike images, the location of a Tweet is associated with where something was said, rather than the location of the object being described.

The third category of data we identified were reviews and check-ins, for example, in the form of Foursquare, Yelp and the now-defunct Whrrl (Ye et al. 2011; Mckenzie and Adams 2017). Interestingly these data were used not only to describe places, but also as a source of place geometry, where the places were essentially the points of interest stored by the services. It is worth noting that these services are typically already available as LBS.

The fourth, and final category of data were unstructured texts, for example, in the form of travel blogs, TripAdvisor entries, Wikipedia pages and the Text +Berg corpus (i.e. Adams and McKenzie 2013; Hobel, Fogliaroni, and Frank 2016; Gao et al. 2017; Derungs and Purves 2016). In unstructured text, more complex methods are required to both relate content to specific places and to extract information related to place. Importantly many of the sources chosen are already associated with places explicitly, for example, in TripAdvisor entries and Wikipedia pages where content associated with specific locations is extracted. An important issue with such texts relates to their availability and copyright associated with them. While Wikipedia texts are freely available under an open licence, this is not the case for TripAdvisor, where content is copyrighted and only available under specific terms.

A number of comments can be made about the data sources chosen in our papers. Firstly, we once again note a strong dose of pragmatism in the choice of data sources – researchers often chose data which were relatively easily available, and where access was free. Secondly, the nature of the data used is heterogeneous, ranging from content with a more or less immediate link to

place (in the form of images and their metadata and reviews) to much less direct links (in the form of Tweets and some unstructured text, for example, articles in the Text+Berg corpus describing Alpine plants or animals). Furthermore, the range of granularities captured in such data, and thus the scales of the places described is not constant, with in particular unstructured text and microblogs capable of capturing information across a very wide range of scales, with important implications for the nature of the context which can be extracted. In the next section, we, therefore, explore the approaches taken to extracting and analysing data such that place could be characterised.

3.3. Data characteristics

Exploring study areas and the time spans over which data were collected gives us some insight into both the potential, and also the limitations, of the approaches taken especially with respect to their use in LBS. All but one study (Adams and McKenzie 2013), chose to limit their study area to specific places at a variety of scales. Furthermore, studies took two essential approaches to linking datasets to places. Derungs and Purves (2016) and Chesnokova, Nowak, and Purves (2017) both used complete corpora covering Switzerland and Great Britain, respectively, and mapped these corpora onto a continuous, field-based, model of place within these countries. All of the other studies we explored either used some form of bounding box (e.g. Resch et al. 2016; Huang 2016) or keywords to identify data associated with specific locations (e.g. Capineri 2016). The data thus collected can be thought of as being related to entities, either in the form of a geometry or a named place. Importantly though, these entities are not necessarily treated as having properties which are constant (e.g. Gao et al. 2017), and nor were they always handled as having sharp boundaries (e.g. Hollenstein and Purves 2010). At their simplest the entities with which properties were associated were represented as points related to points of interest (Ye et al. 2011, Mckenzie and Adams 2017), while more complex entities represented linear features (i.e. Kilburn High Road or the High Line (Capineri 2016; Dunkel 2015)) or areal features (e.g. Gao et al. 2017). Although the papers we explored generally did not discuss in detail issues of inequality in data production (Graham, Hale, and Stephens 2012), we believe that these issues make global modelling of place challenging and highly subject to bias. Thus, the often implicitly taken decision to concentrate on individual cities or countries, appears to make sense when using individual data sources.

The temporal variation in data used to characterise places varied widely, from a minimum of one day to one week (Resch et al. 2016) to a maximum of 152 years (Derungs and Purves 2016). However, we observe that in general authors appear to have chosen time scales either based around meaningful events (Resch et al. 2016), an implicit requirement to collect sufficient data to

write a paper (e.g. Shelton, Poorthuis, and Zook 2015) or simply by analysing the complete corpus available (e.g. Derungs and Purves 2016). We think all three of these positions are justifiable, but note that the sampling period will influence the nature of the context which can be analysed and used in downstream LBS, since short-sampling periods cannot capture cyclical events, while long sampling periods may capture variation which represents, for example, change in language use over time rather than changes occurring to places (Nguyen et al. 2013).

Another key question with respect to data characteristics concerns the way in which the data themselves are localised, and how this localisation is then linked to places. The majority of data in the selected papers had explicit coordinates, though as discussed above, these coordinates may be associated with places of differing granularities. This issue is actively exploited in work concerned with vernacular places and vague cognitive regions (e.g. Gao et al. 2017). We would argue that even where coordinates are stored as metadata, more consideration should be given to the ways in which these points are then linked to places, and indeed to the challenges of matching datasets collected in such ways.

These issues become more apparent when working with data where location is conveyed indirectly through a placename. In the studies we explored, methods were used to both identify placenames and link these explicitly to locations (e.g. Adams and McKenzie 2013; Derungs and Purves 2016). Both of these papers chose to link the coordinates assigned to placenames to relatively coarse grids, thus explicitly representing some form of uncertainty in the granularity of descriptions of places. However, such coarse grids, though at least addressing the issue of granularity explicitly, will typically represent place as unchanging context for large distances with respect to LBS.

The third characteristic we explored was language. Even though the papers we analysed focused almost exclusively on textual content, only eight articles specified the analysed language(s). Of these, two processed German as well as English (Hauthal and Burghardt 2013; Hollenstein and Purves 2010), and one analysed text only in German (Derungs and Purves 2016). In general, by exploring the results presented, it was clear that English was favoured, even in locations where it is not an everyday language. This dominance of English in the papers we analysed, which despite its popularity is clearly not representative of the population as a whole, has several implications. Firstly, there is a tendency to conduct studies in English-speaking countries, and to subsume place into context related to English-speaking cultures. Secondly, the dominance (and good performance) of natural language processing methods in English may result in an unrealistic homogenisation of place-related concepts, where in reality much more diversity may actually be present. Thirdly, by using English in places where the language is not spoken, unrepresentative sources may be favoured (e.g. those used by tourists) creating a further negative feedback in terms of the representation of such places (c.f. Graham et al. 2014).

4. Place dimensions

We chose to use Shatford's (1986) model, since in previous work (e.g. Edwardes and Purves 2007) this has proved a reliable and powerful way to explore different aspects of spatial descriptions. In the following, we focus not only on exploring where papers belong in this model, but also the ways in which individual facets are represented.

We relate the *specific of* to concrete ways in which places are named, that is to say, the use of placenames, be they related to administrative or vernacular usages. Generic terms such as *downtown* or the *city centre* become specific when they refer to a particular place. The most important papers relating to the *specific of* are thus those motivated by place names (Hollenstein and Purves 2010; Hobel, Fogliaroni, and Frank 2016; Gao et al. 2017). In these papers, a number of contrasting aspects are explored. All three look at delineating regions associated with specific place names, whether through the use of density surfaces (Hollenstein and Purves 2010), machine learning (Hobel, Fogliaroni, and Frank 2016) or clustering and polygon approximation (Gao et al. 2017). Hollenstein and Purves (2010) also explored the use of specific terms in the contiguous USA, thus identifying places more likely to be referred to as Downtown at a range of scales. Gao et al. (2017) provide a bridge to the next facet in Shatford's classification, the *generic of*, by generating thematic characteristics related to the cognitive regions SoCal and NorCal (Southern California and Northern California) using Latent Dirichlet Allocation. The resulting topics are dominated by generic terms such as desert, beach, mountain and road which give some insight into the properties of these regions. This representation of the *generic of* as a bag of words, often associated with a rank is typical of many of the approaches we looked at (c.f. Adams and McKenzie 2013). Thus, Capineri (2016) mapped terms onto a similar place model (Agnew 1987) and counted terms representing different activities and objects. Dunkel (2015) also related tag frequencies to particular places, though he did not discriminate between placenames and other classes. Derungs and Purves (2016) used a filtered list of nouns, which they claim captures landscape variation in German to capture generic properties of landscape, and they show how locations can be compared using vectors of terms representing individual grid cells.

Shatford, in her characterisation of the *about* facet, describes it as a way of symbolising a place through a locale, or communicating abstract thoughts (e.g. paradise) through a place. Despite our initial expectations, we found that in many instances the *about* facet was the most appropriate home for studies we explored. Thus, though Gliozzo, Pettorelli, and Haklay (2016) count pictures and users, they do so to represent the abstract notion of cultural ecosystem services, while Chesnokova, Nowak, and Purves (2017) use image ratings to model landscape preference, which again, we argue can be considered to relate to an abstract concept (beauty) of places.

Indeed, many of the papers we explored sought to both map and interpret, typically through the use of word clouds or other relatively simple techniques, the semantics associated with preferences for particular places (e.g. Adams and McKenzie 2013; Dunkel 2015). Other approaches which clearly are linked to this more abstract notion of place are those which seek to link emotions about urban locations to time or day of the week or season of the year (Hauthal and Burghardt 2013; Resch et al. 2016). Lim et al. (2018) seek to characterise both the *generic of* (in the form of green areas in an urban setting) and their properties with respect to the *about* facet through sentiment analysis. They move beyond simple quantification of negative and positive sentiment to also explore the nature of emotions (e.g. anger or joy) associated with different urban settings, showing that particularly negative sentiments are often associated with transport infrastructure and explore how these sentiments change over time.

Perhaps the most abstract example is the work of Shelton, Poorthuis, and Zook (2015). They argue for understanding places in terms of the ways they are experienced and moved through, and the importance of relating data points to one another. Their analysis though, is typical of many of the papers we explored, where the *about* facet can only be understood through a high level of interpretation and contextual knowledge brought to the data by the authors. This difficulty is expressed succinctly by Capineri (2016):

> …feelings and emotions are not always expressed by single words like happy, unhappy, love or hate but rather with expressions of more than one word that reveal the state of mind. …only a limited number of records contain emotional expressions which can be linked to the categories.

A few points are worthy of note here. Firstly, real data capture and can represent all three facets of where, as modelled by Shatford. Using this model it is possible to show how places can be delineated and assigned membership values in terms of their names, and how they can be compared and represented as thematic regions. Furthermore, even using simple counts, it is possible to make effective links to more abstract concepts such as aesthetics. However, an important note of caution should also be sounded. We observed that in particular for the more abstract shared notions, which might be best mapped onto sense of place, a great deal of subjective interpretation was performed. Calls to, for example, use data capturing perceived safety in routing (such as emotions derived from social media), may reinforce or even generate inequalities in our understanding and use of place (c.f. Andreas and Mazimpaka 2016). This adds weight to Shelton et al.'s caution to not simply analyse social media, but rather 'construct empirically grounded counter-narratives of these inequalities' (Shelton, Poorthuis, and Zook 2015, 210).

5. Implications and discussion: opportunities and challenges for the place-based modelling in LBS

Having explored the ways in which place information has been extracted from a range of data sources, and analysed some key properties thereof, we now return to the use of the extracted information in the context of LBS. We used the list of application categories for LBS proposed by Basiri et al. (2015) to provide a skeleton for this discussion. Basiri et al. define their categories based on the spatial and temporally related positional requirements for the LBS itself – for example, the need for navigational systems to be precise. However, our focus is on how place-related information could be used to enhance such services, either taking the form of context associated with a place, or being context in and of themselves. We do not claim to be comprehensive, but rather select examples from three domains: navigation and tracking; marketing and location-based information retrieval where we see the most potential use for place-related information. In the following, we present what we see as some key opportunities, and discuss some of the potential challenges and limitations in the use of place-related information in LBS.

LBS used in navigation and route finding typically relies on highly precise, complete data and accurate real-time location to provide context and feedback to the user. However, specifying a route requires that a user input a target destination (assuming that they are travelling from their current location). Specifying target locations in terms of coordinates or exact addresses is in many cases challenging because these are not natural ways for humans to communicate about locations. Incorporating representations of place related to the *specific of*, that is to say placenames commonly used in a particular area, would be one potential way of improving and facilitating such interaction. Using hierarchies of such places, based on UGC, would provide a mechanism for zooming in and out (Richter et al. 2013), and adjusting the requirements of a route to the needs of a user. For example, a requirement to take me Downtown could be met by a general direction along main thoroughfares with a resultantly low cognitive load, rather than complex directions navigating individual streets to arrive at a particular address Downtown. Representing such initial destinations as a generalised geometry, for example, in the form of a bounding rectangle or an alpha shape (Twaroch, Purves, and Jones 2009; Keßler, Krzysztof, and Mohamed 2009), is one approach to dealing with the vagueness inherent in such regions.

In terms of tracking, such information representations could provide a more meaningful way to aggregate user information than purely geometric regions, providing a bottom-up model of the places visited by groups of users (c.f. Huang 2016). In both cases, there is a need for such information to be stored in more amenable data structures, such as the place graphs originally proposed

by Vasardani et al. (2013) and used by Kim, Vasardani, and Winter (2017). These are designed to be closely related to the ways that humans (rather than machines) reason qualitatively about places. They are well suited to both capturing some notion of vagueness, and hierarchy, with a key challenge then lying in mapping such data back onto the more precise geometry and network used in typical routing systems.

Information classified as *generic of* can provide important additional context in both navigation and tracking. In the latter, it may help to annotate user behaviours before these are analysed, for example, by identifying all users who visited similar locations (c.f. Adams and McKenzie 2013; Derungs and Purves 2016) characterised not simply as a place-type associated with a point, but, for example, as a vector of terms associated with regions, for which similarity measures can then be calculated (Janowicz, Raubal, and Kuhn 2011).

In routing, arguments have already been made for using such information in, for example, modelling more pleasant routes (as represented by tourist flows or semantics attributed to pictures) (Prelipcean, Schmid, and Shirabe 2015; Alivand and Hochmair 2013). However, incorporating such forms of context in LBS requires that we also think about the potentially deleterious effects of such algorithmic solutions. Beauty (and other abstract notions) are inherently human constructs and as such are biased by the communities creating the data. Thus, they may, even through seemingly innocuous applications, reinforce prejudices by, for example, generating routes which avoid certain parts of a city (c.f. Shelton, Poorthuis, and Zook 2015).

The use of LBS in navigation, where users actively seek information, and tracking, where user position is analysed with respect to context, naturally leads to our next major domain area, the use of LBS in marketing products and services based on current, past and predicted location and associated context. Thus, for example, by using *generic of* place information to describe activities from previous and current visitors, it is possible to generate movement profiles which suggest likely activities (and thus can trigger location-based advertising) (Kõivumägi et al. 2015). Starting from a place-based model has several potential advantages. Firstly, as we have seen, such models need not be linked with individual POIs, but can rather take the form of continuous grids (protecting privacy by allowing obfuscation of position (Nussbaum, Omran, and Sack 2017)). Secondly, such models could potentially allow for geofencing approaches (Rosenkrans and Myers 2018) to the triggering of such adverts based on meaningful places, rather than administrative boundaries which may have little to do with the ways in which places are experienced. Since many of the papers which we analysed not only attributed places, but also identified them, such approaches can also be seen as powerful ways of generating context for recommendation systems in marketing and more general retrieval contexts (Huang 2016; Ye et al. 2011), our third potential application area. Here we see essentially three key advantages. Firstly, as in navigation and tracking,

place-based models allow us to move away from precise geometric information, and to generate query footprints for information related to places as actually experienced. Since different data sources capture information about different user groups (Gao et al. 2017), and since user groups can be filtered based on behavioural patterns (Huang 2016), then it is also possible to generate query footprints appropriate to different groups (e.g. a representation of the city centre which is appropriate from the perspective of a tourist visiting a location, as opposed to a local). Secondly, by building place-based hierarchies it should be possible to make proximity queries which are not purely based on distance buffers, and rather use more natural topological representations of locations (e.g. the notion that a place is contained or adjacent to another). Such hierarchies need not only take account of place geometries, but also place semantics, as proposed by Gao et al. (2013), who demonstrated the use of *platial-buffering* based on semantic relations between places derived from linked data. Such approaches allow us to focus more on the semantics of place, and reduce the importance of geometric representations. Having built an appropriate hierarchy places can be queried for other contained or overlapping places. Thirdly, place-based models can potentially allow for indexing of documents taking into account both properties related to the *generic of* and *about sensu* Shatford. By doing so, it should be possible to move towards LBS for specific contexts such as tourism which return, for example, information about castle like locations which are considered haunting, or beautiful beaches in a location-based context.

Despite the obvious and demonstrable potential of using information related to place in LBS, there are a number of important limitations in going down this road. The first, and most important, is that data-driven approaches, as is increasingly being recognised, will reflect the inaccuracies, biases and gaps present in the data used (Graham, Hale, and Stephens 2012; McKenzie et al. 2015; Zook et al. 2010). This means that any services developed in such ways must, from the beginning, clearly state what limitations arise from the data used. However, these limitations are not specific to LBS developed taking a place-based perspective. Rather, since studies of place are often inherently critical, then these issues are more likely to emerge (c.f. Shelton, Poorthuis, and Zook 2015). The second major limitation also concerns data availability. Different services are more or less popular with different user groups in different locations (Van Zanten et al. 2016) leading to no *one size fits all* solution to modelling any aspect of place. This is reflected through the lack of attempts at modelling place-based properties globally, and explains why so many of our papers focus on specific examples. A third challenge, and possible route towards solving such problems lies in the development of approaches to link data from different sources to fill such gaps. Currently, most authors use either single data sources, or compare data sources, but direct linkages and integration of such heterogenous data are rare and difficult.

6. Conclusions

In 2001, Dey emphasised the importance of place as potential context, and in 2014 Farrelly argued for the irreplacibility of place information in LBS. Despite these prescient statements, we argued in the introduction that place is still largely simplified or neglected in LBS. By performing a targeted literature review we wished to explore what sorts of place information can be extracted from available data, and also suggest some opportunities and challenges for using such information in LBS. Our study is limited to the set of papers we chose, which were purposively sampled to cover a particular set of criteria. However, we believe that the analysis of these papers illustrates some of the opportunities and challenges for the use of place-based information in LBS.

The first key opportunity arises from the volume of work which has already been done. By using Shatford's model we were able to identify papers which explored both *specific of* and *generic of* aspects of where – in other words, which looked not only at how places were named, but also their properties. We were surprised to find so many papers also exploring more abstract notions, related to the *about*. A number of authors explored detailed notions such as aesthetics (Dunkel 2015; Chesnokova, Nowak, and Purves 2017) or segregation (Shelton et al.) typically by choosing one aspect and then carrying out detailed interpretation of ways in which this aspect was captured in user-generated content. Often the semantics related to the content and its location was interpreted by the authors in useful and thought-provoking ways. In terms of generating LBS, this means that methods are available to derive complex place properties, but that these have typically to date been only applied to answer individual questions, rather than characterise places more generally. Our results suggest that a plethora of place properties can already be modelled, and that by exploring existing work much richer and more multi-dimensional place context could be created.

The second opportunity lies in the nature of the data used in this work, and the specific needs of LBS. Systems for use by humans should communicate with humans in ways which reflect human spatial cognition, rather than data models imposed by computers. Our analysis showed clearly that natural language was often analysed, and available, to characterise places. This, in turn, provides a host of opportunities for developing systems which put language, rather than geometry, at the forefront in not only querying, but also presenting information to users. Furthermore, our analysis suggests a number of ways in which data models might be improved beyond simple point-based representations (for example, by using topology, linking place properties to continuous fields, or building place graphs) which could, in turn, allow more imaginative services to be developed.

In parallel with these opportunities, a number of dangers and challenges arise in using place-based information in LBS. The greatest of these lies in the

potential impacts of biased data and algorithms developed to take advantage of such data. Although these concerns are not unique to LBS (Boyd and Crawford 2012), and nor do they only arise when we used place-based methods, we think they are especially important in this context. Paying attention to place as a concept has a long history in human geography and is concerned with better understanding shared and plural ways of thinking about place. Methods which use place should remember these critical beginnings, and ensure that they do not replicate, or even reinforce inequalities.

The final challenge we see for the development of LBS using place-based concepts arises from the nature of the data and studies which we analysed. It is clear that no single dataset, nor a single method, will allow us to characterise place everywhere. Developing generalisable services however requires that the community address the considerable challenge of integrating place information with widely varying semantics and spatial and temporal granularities. Only by approaching this challenge in a systematic way will it be possible to start to put together the pieces of the jigsaw, and develop place-based LBS which better address real-world needs.

Note

1. http://schema.org/Place.

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